Industrial and Systems Engineering Review, 7(1), 2019
Shi *et al.*

ISSN (Online): 2329-0188

A Value Model Approach to Reduce PM Cargo's Costs for the CH-47F Chinook Helicopter

Heidy Shi, Carlos Garcia, Jack Kesti, Christopher Lee, and David Hughes

Department of Systems Engineering
United States Military Academy
West Point, NY, 10996, USA

Corresponding author's Email: heidy.shi@westpoint.edu

Author Note: The authors listed above are currently seniors at the United States Military Academy at West Point and worked under the direction of their advisor, LTC David Hughes. This project was completed as part of a graduation requirement for their senior capstone course. They are working with Project Management (PM) Cargo, the owning organization for the CH-47F "Chinook." The authors would like to thank PM Cargo, the Department of Systems Engineering, and LTC Hughes for all their support.

Abstract: The CH-47F is a multifaceted system incorporating a series of technological improvements that aim to improve flight crews' performance. The new Chinook model marks a transition away from platforms with steam gauge based cockpits, federated mission systems equipment, and analog flight control augmentation systems. The aircraft has a highly integrated glass cockpit and digital flight control augmentation system reducing the crew's workload and improving other capabilities, such as auto-hovering. This allows pilots to focus on aspects essential for mission success while operating in challenging environments. PM Cargo is responsible for maintaining the CH-47F to meet these demands, however, this has significant financial challenges to consider. PM Cargo asked us to produce courses of action that will reduce costs while also adding value to the CH-47F program. This will ensure the CH-47F, through PM Cargo's stewardship, remains a staple of the United States Army into the future.

Keywords: Value Focused Thinking, Value Model, Cost Analysis

1. Introduction

1.1 Project Motivation

The new Chinook model marks a technological transition to a highly integrated glass cockpit and digital flight control augmentation systems. These new features provide soldiers with capabilities essential towards accomplishing their complex missions in arduous conditions. PM Cargo is developing the CH-47F with the Common Avionics Architecture System (CAAS) flexible management system within the aircraft to provide the Army with a cargo helicopter capable of enhancing soldier effectiveness by reducing the flight crew's workload (Clements & Bergey, 2005). The CAAS is implemented in the CH-47 and the UH-60 (Rockwell Collins, 2012). Like all complex software, the CH-47F avionics software must consistently undergo updates to stay current with new releases in technology. The process is as follows: Rockwell Collins first develops the software and tests the system integration of new software. The software then goes to Boeing, a competing contractor, for independent validation and verification, to provide validation by an outside party. Once Boeing has verified these updates, the Army (PM Cargo) begins conducting tests of the software. The process is extensive and requires multiple steps to implement a change where each update can cost as much as $11,000 per hour of flight testing. PM Cargo has asked to identify inefficiencies in its software update process that are inflating the costs of maintaining the CH-47F.

The initial problem statement focused on reducing hardware and software costs for the overall development and maintenance of the CH-47F. Research was conducted to create a baseline understanding of the CH-47F's modernized capabilities and software requirements. This served as a base understanding of the Chinook and to identify potential areas that are most costly. By analyzing how PM Cargo is developing, integrating, and testing the new capabilities for the CH-47F, the scope was narrowed to focus exclusively on the software updates and the testing verification process. Multiple interim progress reports (IPRs) were conducted to ensure stakeholder requirements were properly implemented into each alternative and that the focus remained on relevant software update processes.

ISSN (Online): 2329-0188

1.1 Methodology: Systems Decision Process (SDP)

The Systems Decision Process (SDP) is divided into four phases and is used as a framework to help make challenging decisions. Figure 1 shows the SDP and its phases: Problem Definition, Solution Design, Decision Making, and Solution Implementation. Each phase of the SDP is also broken down into three key components. The SDP uses value-focused thinking to create and evaluate alternatives. It requires access to key stakeholders and experts and illuminates key issues. This project uses the first three steps of the SDP to create possible solutions that will save PM Cargo money in their update process.

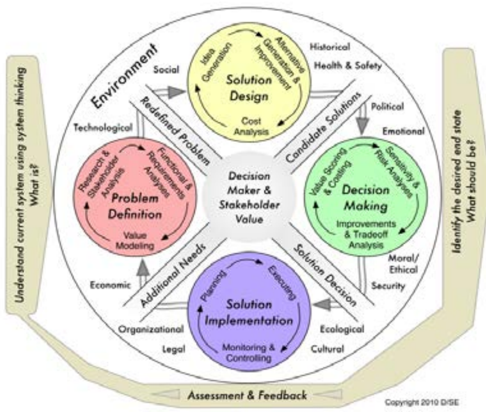

Figure 1. Systems Design Process (SDP)

2. Problem Definition

2.1 Functional Hierarchy

A functional hierarchy (Figure 2) was created to develop the functions and sub-functions that would support PM Cargo. The fundamental objective focuses on streamline software maintenance and upgrades. It is broken down into four main functions: (1) improve maintainability, (2) refine software integration, (3) create incentives, and (4) diversify testing environments. Function 1 addresses the scheduled software updates' variability to establish a more structured schedule. This will provide PM Cargo with a clear software update timeline and improve the software's structure to reduce the amount of time PM Cargo spends isolating issues in the software. Function 2 focuses on the software integration inefficiencies caused when PM Cargo attempts to test both large and multiple updates. Function 3 addresses Boeing's role in the CAAS software update process described previously. Third party companies such as Boeing often fail to produce the most efficient feedback to ensure continued dependence from PM Cargo. This function aims to develop an incentives process that will attract various companies to form partnerships and pressure those third-party companies to produce effective and timely feedback. Function 4 seeks to assess other environments with aviators and aircrafts that can provide more or equal value at lower costs to PM Cargo's current testing locations in Huntsville, Alabama and Fort Rucker, Alabama. These main functions were broken down into two sub-functions. This functional hierarchy is a framework for understanding how PM Cargo can reduce costs through streamlining software maintenance and upgrades.

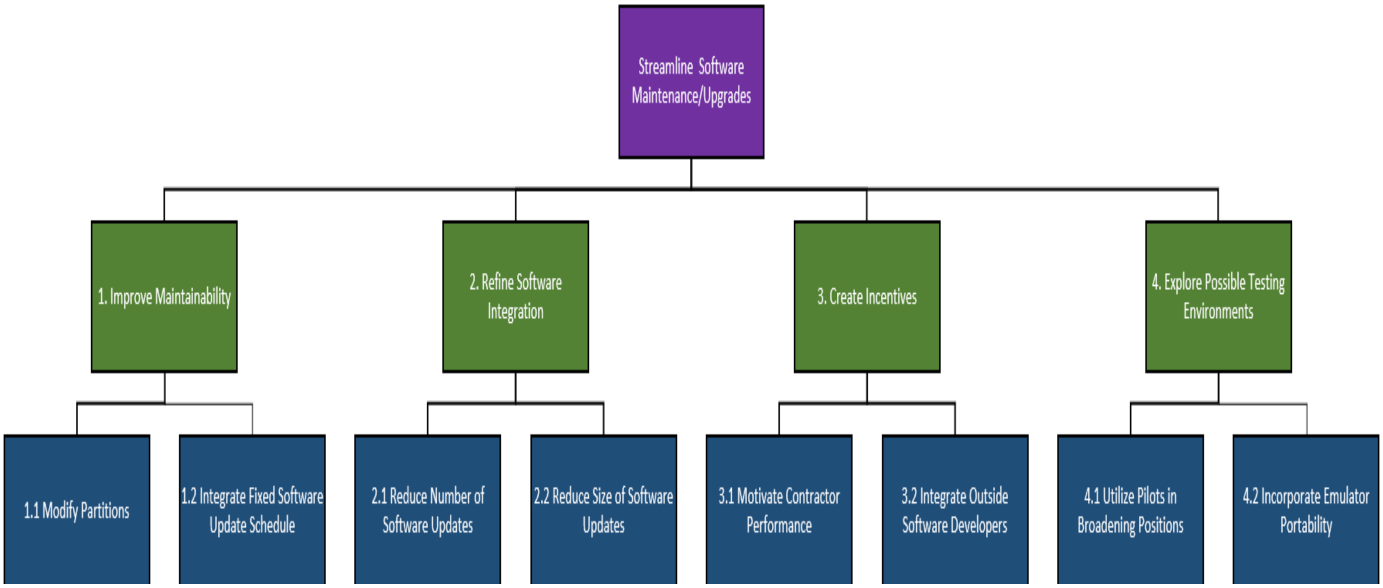

Figure 2. Functional Hierarchy

2.2 Qualitative Value Model

Figure 3 shows the qualitative model that was produced for Function 4 from the functional hierarchy. Objectives “Maximize Relevant Testing Population” and “Maximize Portability” were developed to provide a preference on how the subfunction will be optimized through the value measures. This project considered the impact on the software testing process when values were designated within each value measure. "Number of People Testing” seeks to assess the availability of aviators at potential locations to quantify the value associated with the size of a testing group at the different locations. “Flight Activity Category (FAC) Level and Type of Aircraft” determines the type of aircraft flown by the aviators at potential locations and how often they operate the aircraft to understand the testing population available at various locations. “Number of Trainers Used” and “Trainers Temporary Duty (TDY) Time” focus on the trainers that PM Cargo must provide to administer the simulator testing process at various locations and the number of days they are required to be TDY. The values assigned consider optimizing the value for trainers’ ability to facilitate testing while they are away from Huntsville, Alabama. These value measures also consider if there is an excessive number of trainers tasked and an excessive number of days TDY that will cause a marginal rate of return of value. “Distance Traveled” establishes the distance that the simulators must travel to the potential testing locations. It is assumed that the further testing environments are from Huntsville, the lower the value due to the challenges associated with coordinating shipments to transport trainers and simulators. “Type of Simulator Used” determines which of the three simulators (CAPT, CAPT-E, and CAPT-EVCS) will be shipped. The assigned values are based on the simulator’s ability to test and provide feedback for the flight software. For example, the CAPT is the least sophisticated flight simulator and will provide the least amount of feedback resulting in the lowest assigned value while the CAPT-EVCS is the most sophisticated simulator so it will provide the most feedback, resulting in the highest assigned value. “Time Testing” measures the value associated with the number of testing hours per week. It is assumed that more value will result from more testing hours.

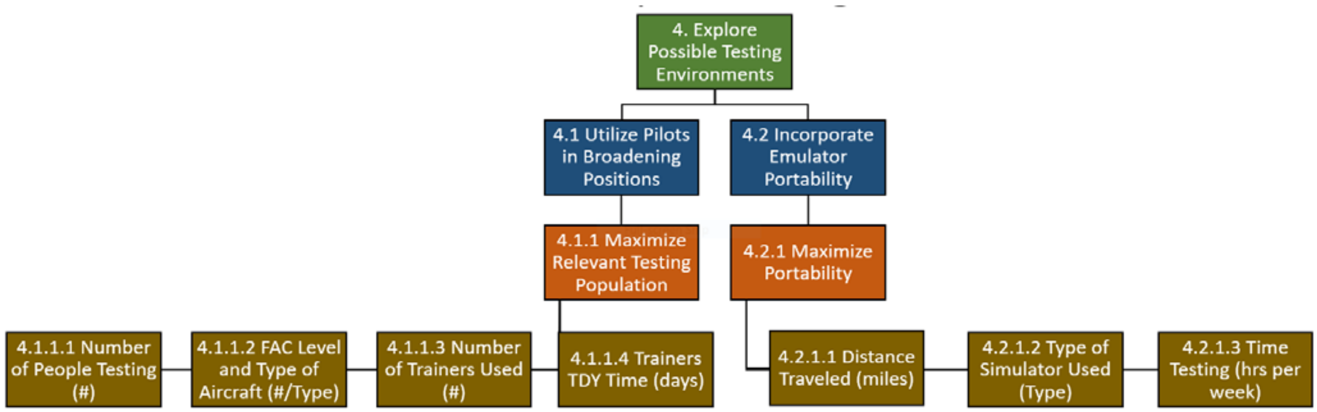

Figure 3. Qualitative Value Model

2.3 Quantitative Value Model

To create a quantitative value model, value functions for each of the value measures were created so that raw data can be converted to a standard unit “value.” Figure 4 shows the different value functions created for each of the value measures. The x and y values, for each of the value functions was created based on stakeholder analysis and stakeholder preferences respectively. Each resulting value represents how much additional value would be added depending on the different alternatives.

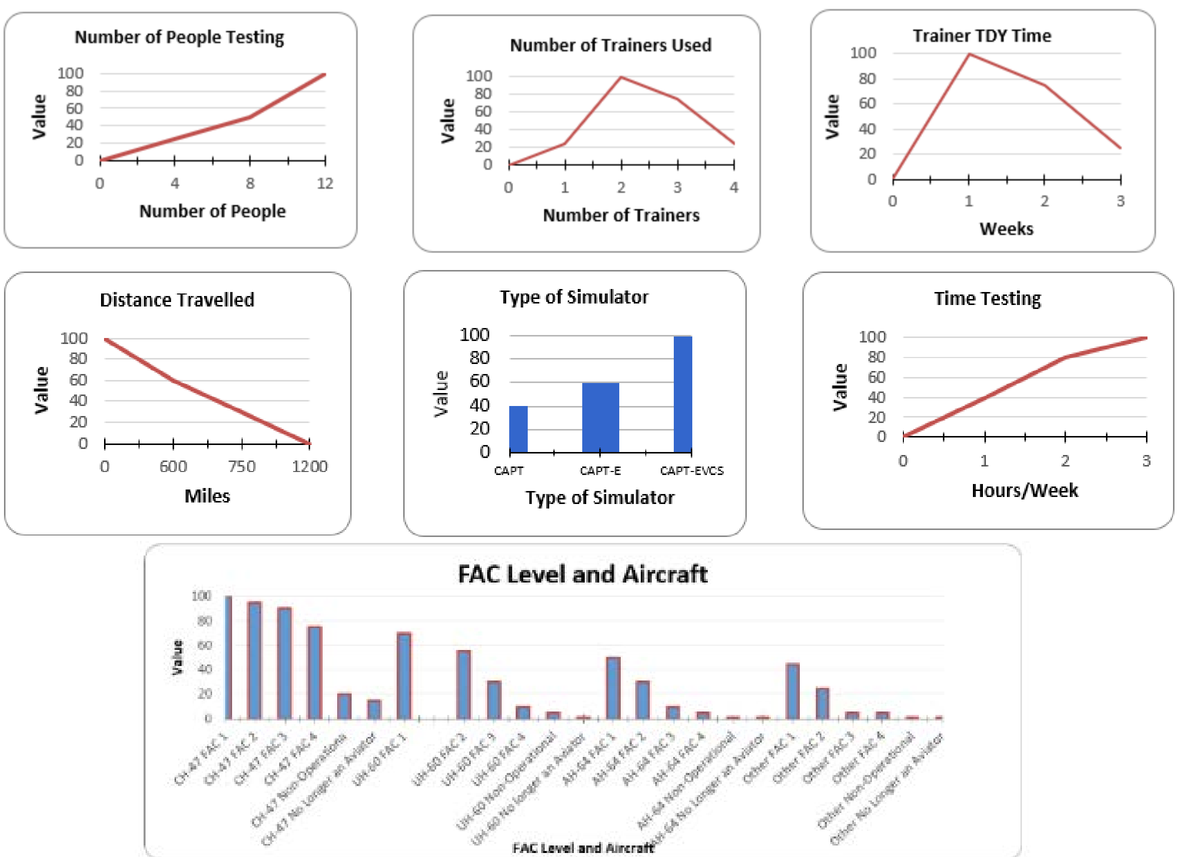

Figure 4. Value Functions

To quantify the relative importance of value measures, weights were assigned to each value measure based on a pairwise comparison completed by PM Cargo. These results provide a quantitative assessment of the significance of each of the value measures (Salkind, 2010). Stakeholder input for each value measure was completed using a pairwise comparison. The matrix was created by comparing each value measure against another value measure. A number was assigned to each where a 4 means the measure is much more important, a 2 means the measure is more important, a 1 if the measure is equal in importance, a 0.5 if the measure is less important, and 0.25 if the value measure is much less important.

Once the pairwise comparison was completed, measure weights were assigned based on the comparison. Table 1 shows the weights generated from the pairwise comparison. The weights show that FAC Level/Aircraft is the most heavily weighted value, because PM Cargo believes that FAC level and experience are most relevant for testing. The next most heavily weighted value measures were the number of people testing and the time testing. This is because PM Cargo believed that the more time and the more people they can test, the better the information, and the more value they receive. The next value measures with the most weight followed in order by type of simulator, trainer TDY time, number of trainers used, and distance traveled.

Table 1. Measure Weights

	Type of Simulator	Time Testing	Number of people testing	Distance traveled	Number of trainers used	Trainer TDY Time	FAC Level/Aircraft
Weights	0.101	0.203	0.203	0.050	0.057	0.078	0.308

3. Solution Design

3.1. Alternative Generation and Improvement

During alternative generation, a morphological box (Figure 5) was used to investigate the total set of possible relationships between components (Parnell et al., 2010). After all the possible combinations were generated, the next step was to screen the ideas to determine which ones were feasible. Feasibility screening was conducted by eliminating solutions that did not meet specific screening criteria. For example, the combination of sending trainers without any TDY time was not possible and was eliminated. The final alternatives are highlighted in Figure 5, with each shape representing a different possible solution.

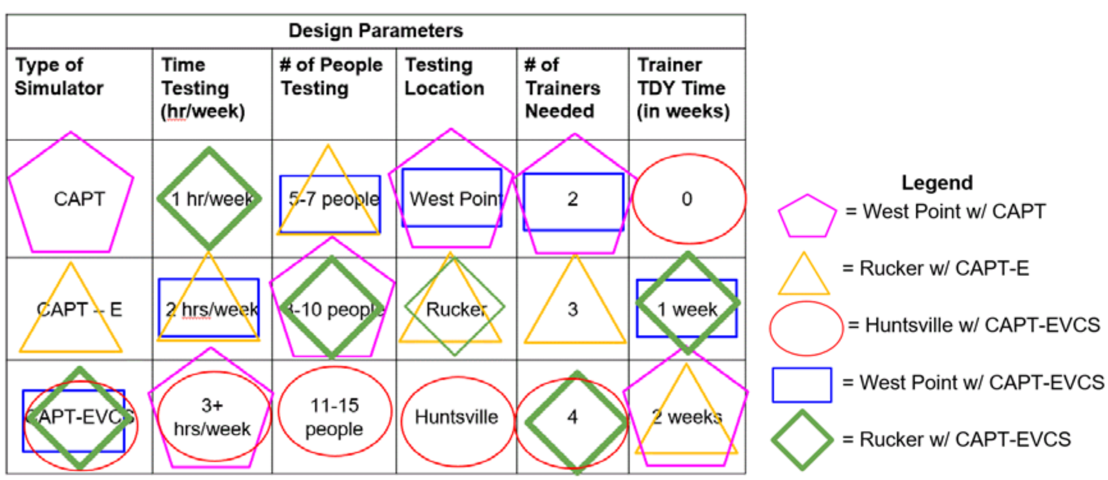

Figure 5. Zwicky's Morphological Box

3.2 Cost Analysis

The main factors that affected cost for each of the alternatives was shipping costs required to transport the simulator and the TDY cost required to send personnel to different training environments. For some testing environments, only trainers were needed while other testing environments required only bringing testers. The TDY costs varied for each alternative because TDY cost was based on the number of personnel needed to travel to the location, the per-diem rates at each location, and how many days personnel spent at each location. The TDY costs varied the most and created the greatest disparity across each of the alternatives. Table 2 shows the cost breakdown for each alternative. From this table, it is evident that CAPT-EVCS at Rucker was the most expensive alternative and CAPT-E at West Point was the least expensive alternative. The number of days TDY refers to the days that a trainer must remain at a location which was determined by how much time would be needed to set up the various simulators. The smaller simulators required an extra week to set up (14 days) because there were multiple simulators brought to each location. The number of TDY testers was 12 for the Huntsville option because that location does not have a population of aviators who would be able to test, so some would have to be brought in. The 12 testers were the average value that PM Cargo gave regarding how they currently use testers in their simulators. There may also be other factors that affect cost but were assumed unimportant because there was no data or input from PM Cargo regarding other cost factors.

Table 2. Cost Breakdown Table (UPS, 2019)

	Personnel					**Shipping**				
Alternatives	# TDY Trainers	# TDY Testers	Cost per Day TDY	# of Days TDY	**Total Personnel Cost**	Type of Simulator	# of Simulators	Distance Traveled	**Total Shipping Cost**	**TOTAL COST**
WP w/ CAPT-EVCS	2	0	$ 171	7	**$ 2,394**	CAPT-EVCS	1	980	**$ 2,305**	$ 4,699
Huntsville w/ CAPT-EVCS	0	12	$ 149	7	**$ 12,516**	CAPT-EVCS	1	0	**$ -**	$ 12,516
Rucker w/ CAPT-E	3	0	$ 149	14	**$ 6,258**	CAPT-E	2	280	**$ 950**	$ 7,208
WP w/ CAPT	2	0	$ 171	14	**$ 4,788**	CAPT	3	980	**$ 483**	$ 5,271
Rucker w/ CAPT-EVCS	4	0	$ 149	7	**$ 4,172**	CAPT-EVCS	1	280	**$ 1,025**	$ 5,197

4. Decision Making

4.1 Value Scoring

Value scoring was conducted using an additive model based on value functions and weights created during the problem definition phase. The additive model allows stakeholders to mathematically represent how important each value measure is to the overall score for each alternative. Figure 6 shows the total solution value for each alternative. Each value measure is represented by different colors so that one can see how significantly each contributed to the overall solution value. For instance, FAC Level and Aircraft heavily contribute to the alternatives “Huntsville w/ CAPT-EVCS,” “Rucker w/ CAPT-E,” and “Rucker w/ CAPT-EVCS.” The bar furthest at the bottom represents an ideal solution, which takes the highest value measure across all the alternatives.

The stacked bar chart illustrates that “Huntsville w/ CAPT-EVCS” wins with the most value. The next best option would be “Rucker w/ CAPT-EVCS.” It is evident that the disparity between the two solution values comes from the “Time Testing” and “Number of People Testing” value measures. The Huntsville option wins out in these two categories, making it significantly better than the Rucker option. However, the Rucker option could be improved by increasing the value in both “Time Testing” and “Number of People Testing” to try and improve its overall value.

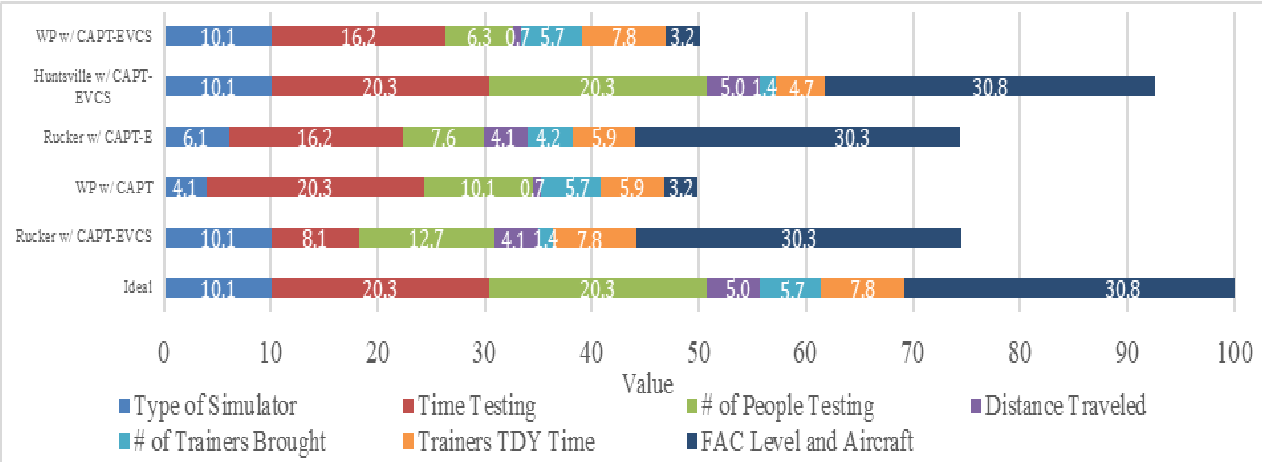

Figure 6. Stacked Bar Chart

4.2 Cost vs. Value

Additionally, once value scores were totaled for each alternative, they can be compared to the costs to see which solutions give the best value for the least amount of cost. Figure 7 depicts a Cost vs. Value graph for each of the five alternatives. Staying at Huntsville provides the most value but is also clearly the most expensive option. The next options with the greatest value are to travel to Rucker with either the CAPT-EVCS or the CAPT-E. The chart shows the two circled solutions, Rucker with the CAPT-E and West Point w/ the CAPT are dominated because each solution costs more but provides less value compared to a better alternative. The chart also shows that both Fort Rucker solutions provide more value but are more expensive than the West Point destination alternatives. The chart shows that the best solutions that are cheaper in costs are either WP w/ CAPT-EVCS or Rucker w/ CAPT-EVCS.

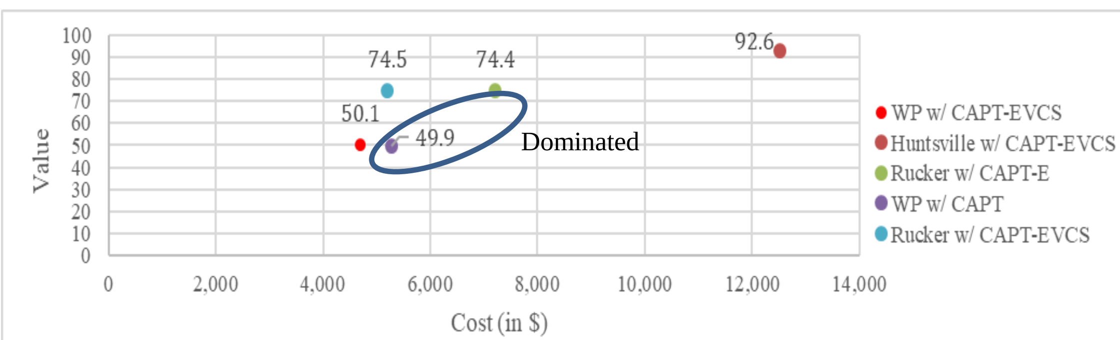

Figure 7. Cost vs. Value

5. Conclusion and Further Research

The value model created will help PM Cargo save money by highlighting the possible candidate solutions from which they can choose the best option. The model shows that the solution with the greatest value is to keep simulation testing at “Huntsville w/ CAPT-EVCS.” However, PM Cargo is looking to find alternatives to reduce costs. The cheapest alternative is “WP w/ CAPT-EVCS" which may not necessarily provide as much value but can still be a possible alternative. Additionally, both Fort Rucker options provide much more value than the WP options, but is also much cheaper than the Huntsville option. Based on our analysis, it will be in PM Cargo’s best interest to explore testing in both Huntsville and Fort Rucker due to the relatively high values and the low cost associated with going to Fort Rucker.

Although the budget for the CH-47 program is large, the savings proposed in the model are small. This is because of the limited data provided by PM Cargo. With more data, the framework created can be used to develop more solutions and further save costs for PM Cargo. Further research can also be conducted by developing a value model for the remaining three functions defined in the functional hierarchy during the problem definition phase. New value measures can be created, and raw data can be collected to analyze the other three functions. This data will allow PM Cargo to mathematically analyze their entire trade space and possibly reduce more costs for the organization.

6. References

Clements, P., & Bergey, J. (2005, September). The U.S. Army's Common Avionics Architecture System (CAAS) Product Line: A Case Study. Retrieved September 24, 2018, from http://www.dtic.mil/dtic/tr/fulltext/u2/a444361.pdf

Parnell, G. S., Driscoll, P. J., & Henderson, D. L. (Eds.). (2011). Decision making in systems engineering and management (Vol. 81). Hoboken: Wiley.

Rockwell Collins. (2012, April 04). US Army CAAS Cockpit. Retrieved from https://www.helis.com/database/news/caas_cockpit/

Salkind, N. J. (2010). *Encyclopedia of Research Design*. Newbury Park, CA: SAGE Publications INC.

UPS (2019). Calculate Time and Cost for Freight. (n.d.). Retrieved March 27, 2019, from https://wwwapps.ups.com/fctc/timeandcost?loc=en_US&ActionOriginPair=SeamlessExperience___StartSession&FREIGHT_TYPE=LTL